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CONTROL-SURFACE HINGE-MOMENT AND ELEVON NORMAL-FORCE CHARACTERISTICS AT TRANSONIC SPEEDS ON A MANNED LIFTING ENTRY VEHICLE

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SUMMARY

Measurements of the normal-force and hinge-moment characteristics of aerodynamic controls have been made on a manned lifting entry vehicle in the Langley 8-foot transonic pressure tunnel to provide aerodynamic design data at transonic speeds. Tests were made at Mach numbers from 0.20 to 1.20 and through an angle-of-attack range from approximately -2° to 24° for elevon deflections from -25° to 25°. Results include hinge-moment characteristics of the elevon, elevon upper-surface flap, tip-fin inner-surface flap, and rudder and, also, normal-force characteristics of the elevon. The results are presented without analysis.

INTRODUCTION

As part of the wind-tunnel program required for the development of a manned lifting entry vehicle having maximum hypersonic lift-drag ratios of about 1, a model of the HL-10 (horizontal lander 10) has been tested in the Langley 8-foot transonic pressure tunnel. Results of force tests for several HL-10 configurations tested in a range of Mach numbers from low subsonic to hypersonic speeds are reported in reference 1.

The purpose of the present investigation was to determine normal-force and hinge-moment characteristics of aerodynamic controls to provide aerodynamic design data. Two configurations were investigated. The first configuration which was instrumented to measure elevon normal force and elevon hinge moment consisted of the basic HL-10 body with center-line fin and canted tip fins. Results of an investigation of the aerodynamic stability and performance characteristics of the first configuration with slightly modified elevon planform are reported in reference 2. The second configuration which was instrumented to measure hinge-moment characteristics of the elevon, elevon flap, tip-fin flap, and rudder consisted of the basic HL-10 body with center-line fin, canted tip

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*Title, Unclassified.

fins, and auxiliary flaps on the tip-fin inner surface and on the upper surface of the elevons. The auxiliary flaps were added to improve transonic longitudinal stability characteristics. The measured hinge-moment characteristics of the elevon, elevon flap, tip-fin flap, and rudder and normal-force characteristics of the elevon without flaps are presented herein without analysis in order to expedite publication.

SYMBOLS

Hinge-moment and elevon normal-force coefficients are based on the area and average chord rearward of the hinge line of the respective elevon, flap, or rudder. Hinge moments are referenced to the hinge line about which the control surfaces were deflected.

The units used for the physical quantities in this paper are given both in the International System of Units (SI) and in the U.S. Customary Units.

C_N normal-force coefficient of elevon, $\frac{\text{Normal force}}{qS_3}$

C_h hinge-moment coefficient, $\frac{\text{Hinge moment}}{qSc}$

c average chord rearward of control-surface hinge line

l reference length of model (model value, 40.64 centimeters (16.00 inches))

M Mach number of undisturbed stream

q dynamic pressure of undisturbed stream

R Reynolds number based on model reference length l

S area of control surface rearward of hinge line

α angle of attack measured relative to reference line of model

δ_e elevon deflection angle measured in plane perpendicular to hinge line, positive with trailing edge down, degrees

δ_r rudder deflection, positive with trailing edge to left, degrees

ϕ fin toe-in angle, angle between model vertical plane of symmetry and fin outer surface measured in horizontal reference plane of model (see fig. 1(c))

ϕ fin roll-out angle, angle between model vertical plane of symmetry and fin outer surface measured in plane normal to fin roll axis (see fig. 1(c))

Subscripts:

1 tip-fin flap

2 elevon flap

3 elevon

4 elevon with flap

5 rudder

APPARATUS

Tunnel

The investigation was made in the Langley 8-foot transonic pressure tunnel. The test section of this tunnel is square in cross section with the upper and lower walls axially slotted to permit changing the test-section Mach number continuously from 0 to above 1.20 with negligible effects of choking and blockage. The total pressure of the tunnel air can be varied from a minimum value of about 0.25 atm $\left(1 \text{ atm} = 0.1013 \text{ MN/m}^2\right)$ at all test Mach numbers to a maximum value of about 1.5 atm at transonic Mach numbers and about 2.0 atm at Mach numbers of 0.40 and less. The tunnel air is dried sufficiently to avoid condensation effects.

Model

Three-view drawings showing details of the HL-10 configuration are presented in figure 1 and the body cross-section ordinates are presented in reference 3. The body and various components are identified as follows:

Basic body B: Original body with no fins, as in reference 3

Fin E_2: Center-line fin

Fin I_3: Tip fins with average roll-out angle $\phi = 8.5^{\circ}$ and toe-in angle $\epsilon = 10.8^{\circ}$

Fin I_4: Tip fins with roll-out angle $\phi = 8.5^{\circ}$ and toe-in angle $\epsilon = 10.8^{\circ}$

Elevon flap: Flap on upper surface of elevon deflected upward 20°

Tip-fin flap: Flap on inner surface of tip fin deflected inward 30°

These model designations were assigned to the model as part of the overall test program numbering system.

Two configurations were included in the present investigation. One configuration (fig. 1(a)) consisted of the basic body with center-line fin E_2 and canted tip fins I_3 with the left elevon instrumented to measure elevon normal force and hinge moments about the elevon hinge line. The I_3 tip fins through an error in construction were unsymmetrical in that the 8.5° roll-out was the average of 9.17° roll-out on the left tip fin and 7.83° on the right tip fin. The second configuration (transonic configuration (fig. 1(b)) included the basic body with center-line fin E_2, the I_4 tip fins which conformed to the average geometry of the I_3 tip fins, and flaps on the upper surface of the elevons and on the inner surface of the tip fins which were added to improve transonic longitudinal static stability characteristics. The upper surfaces of the elevons were boattailed 8° (see fig. 1(b)) when the flaps were added. The elevon and flaps were instrumented to measure hinge moments about their hinge lines. The rudder on the trailing edge of the center-line fin was deflected -20° and instrumented to measure rudder hinge moments for most of the tests on the second configuration.

Although the elevon planform areas were the same for the two configurations, different reference areas were used in data computations and are as follows:

Control surface	Symbol	Reference area, cm^2	Reference chord, cm
Tip-fin flap	$C_{h,1}$	7.81	1.40
Elevon flap	$C_{h,2}$	24.65	3.53
Elevon without elevon flap	C_N and $C_{h,3}$	29.03	4.57
Elevon with elevon flap	$C_{h,4}$	33.61	4.62
Rudder	$C_{h,5}$	16.32	2.08

Instrumentation

Forces and hinge moments for the tip-fin inner-surface flap, elevon upper-surface flap, elevon, and rudder were measured by individual strain-gage balances. The model was supported by a conventional sting which, in turn, was attached to the remotely controlled model support system. Forces and hinge moments on the individual control surfaces and the angle of attack were recorded electronically on punch cards.

TESTS, CORRECTIONS, AND ACCURACY

Tests

The investigation was made at Mach numbers from 0.20 to 1.20, at stagnation pressures from 1 atm at Mach numbers of 0.60 and 0.20 to approximately 1/3 atm at a Mach number of 1.20, and at a stagnation temperature of 322° K (120° F). The Reynolds number and dynamic pressures of the investigation are shown in figure 2. The tests were made at angles of attack from approximately -2° to 24° at a constant sideslip angle of 0°.

The investigation included tests to determine elevon normal-force and hinge-moment characteristics for the configuration with the center-line fin E_2 and tip fins I_3 and hinge-moment characteristics of the tip-fin inner-surface flap, elevon upper-surface flap, elevon, and rudder for the configuration with the center-line fin E_2, canted tip fins I_4, and transonic flaps. Elevon deflections from -25° to 25° were investigated.

All configurations were tested with a 0.25-cm (0.10 in.) strip of No. 60 carborundum grit along the 12.5-percent-chord line on upper and lower body surfaces. A similar strip, located around the body 5.08 cm (2.00 in.) from the nose, was included on the configuration with the transonic flaps.

Corrections

The aerodynamic force and moment data presented herein are considered to be free of tunnel boundary interference. The angle of attack has been corrected for the deflection of the sting support system under aerodynamic load.

Accuracy

Consideration of the factors affecting the accuracy of the results indicates that the measured coefficients are accurate within the following limits:

For Mach number of 0.80:

$C_{h,1}$	±0.031
$C_{h,2}$	±0.052
$C_{h,3}$	±0.008
$C_{h,4}$	±0.003
C_N	±0.006

Angle of attack α is accurate to within ±0.10° and Mach number is accurate to within ±0.005.

The deflection of the elevons due to aerodynamic loading is estimated to be within ±0.20°. The deflection of the rudder and transonic flaps due to aerodynamic loading has not been assessed but is estimated to be less than that of the elevons.

For Mach numbers other than 0.80 for which the dynamic pressures were substantially less than that at $M = 0.80$, the accuracy of the data expressed in aerodynamic coefficient form was correspondingly poorer than that given in previous table. The relatively poor accuracy of the hinge-moment data for the tip-fin flap $C_{h,1}$ and elevon flap $C_{h,2}$ suggests that the data be used only to indicate trends and perhaps to indicate envelope values.

RESULTS

Normal-force and hinge-moment characteristics for the basic body with center-line fin E_2 and tip fins I_3 are shown in figure 3 and hinge-moment characteristics for the basic body with center-line fin E_2, tip fins I_4, and transonic flaps are shown in figure 4. These results are presented without analysis except to note the substantial positive increase in elevon hinge moments with the addition of the elevon upper-surface flaps.

CONCLUDING REMARKS

Measurements of the normal-force and hinge-moment characteristics of aerodynamic controls have been made on a manned lifting entry vehicle in the Langley 8-foot transonic pressure tunnel to provide aerodynamic design data at transonic speeds. Tests were made at Mach numbers from 0.20 to 1.20 and through an angle-of-attack range from approximately -2^{o} to 24^{o} for elevon deflections from -25^{o} to 25^{o}. Results included hinge-moment characteristics of the elevon, elevon upper-surface flap, tip-fin inner-surface flap, and rudder and, also, normal-force characteristics of the elevon.

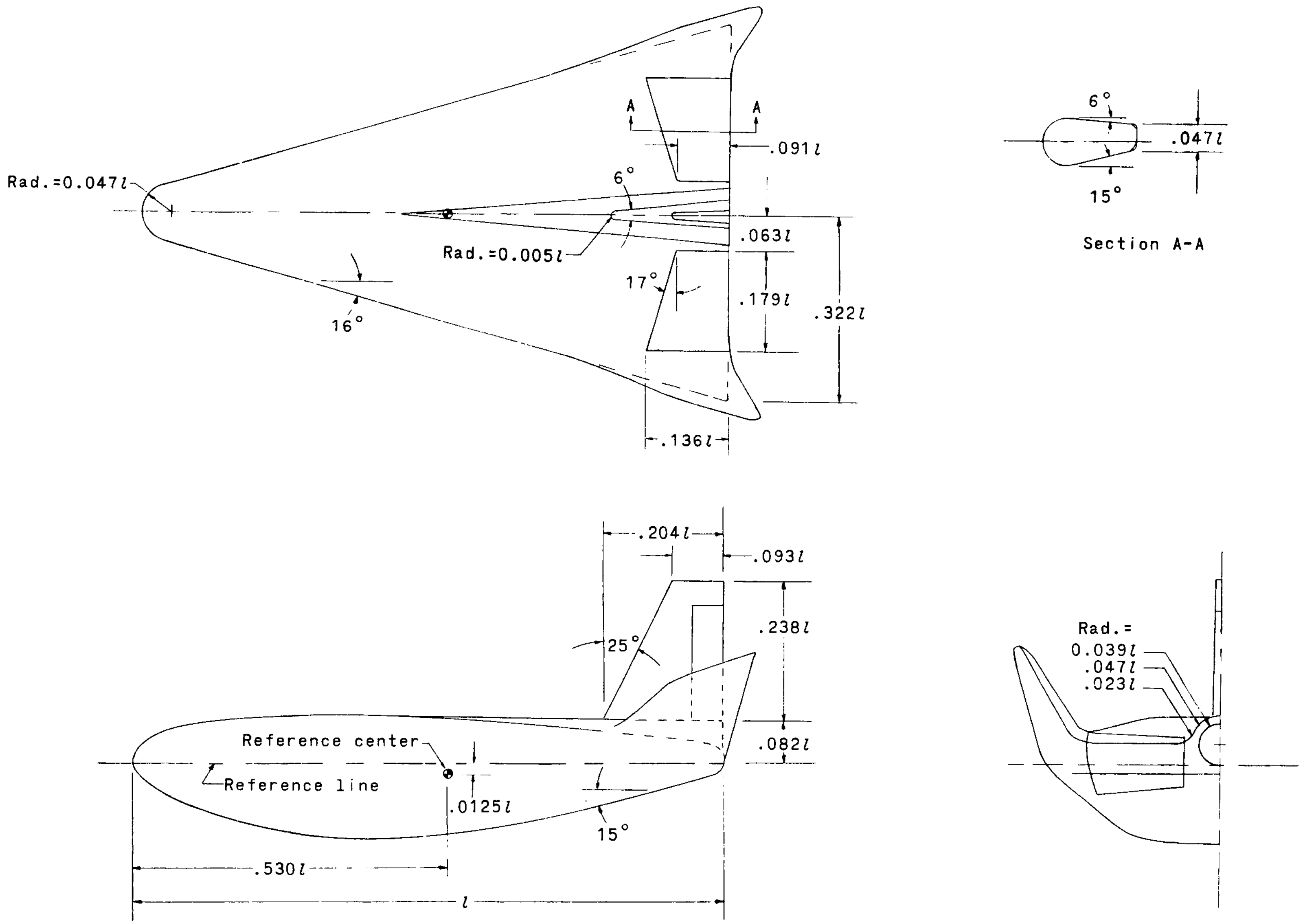
Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., February 23, 1966.

REFERENCES

1. Rainey, Robert W.: Summary of an Advanced Manned Lifting Entry Vehicle Study. NASA TM X-1159, 1965.

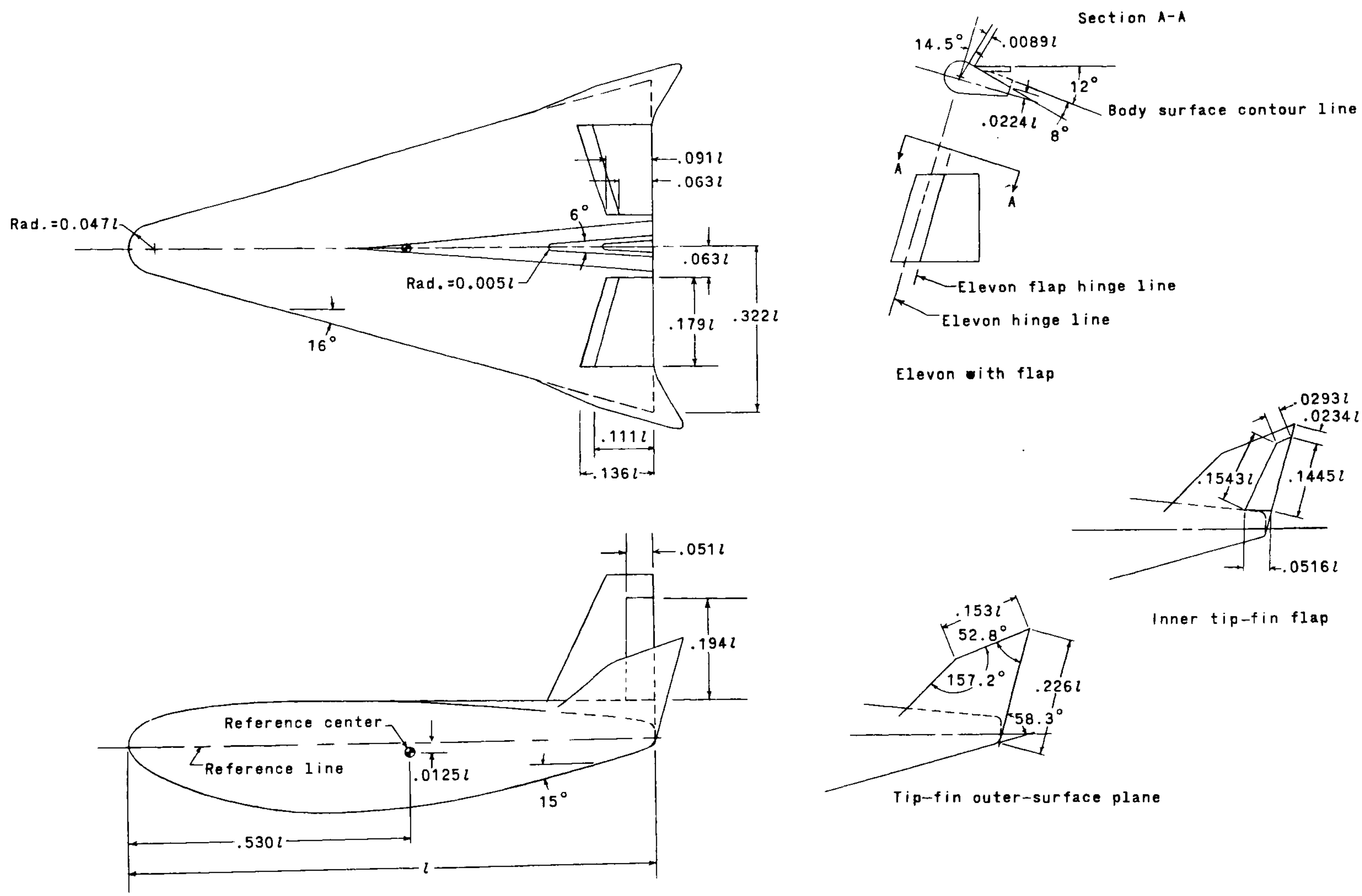
2. Harris, Charles D.: Effect of Elevon Deflection and of Model Components on Aerodynamic Characteristics of a Manned Lifting Entry Vehicle at Mach Numbers of 0.20 to 1.20. NASA TM X-1226, 1966.

3. Rainey, Robert W.; and Ladson, Charles L.: Preliminary Aerodynamic Characteristics of a Manned Lifting Entry Vehicle at a Mach Number of 6.8. NASA TM X-844, 1963.



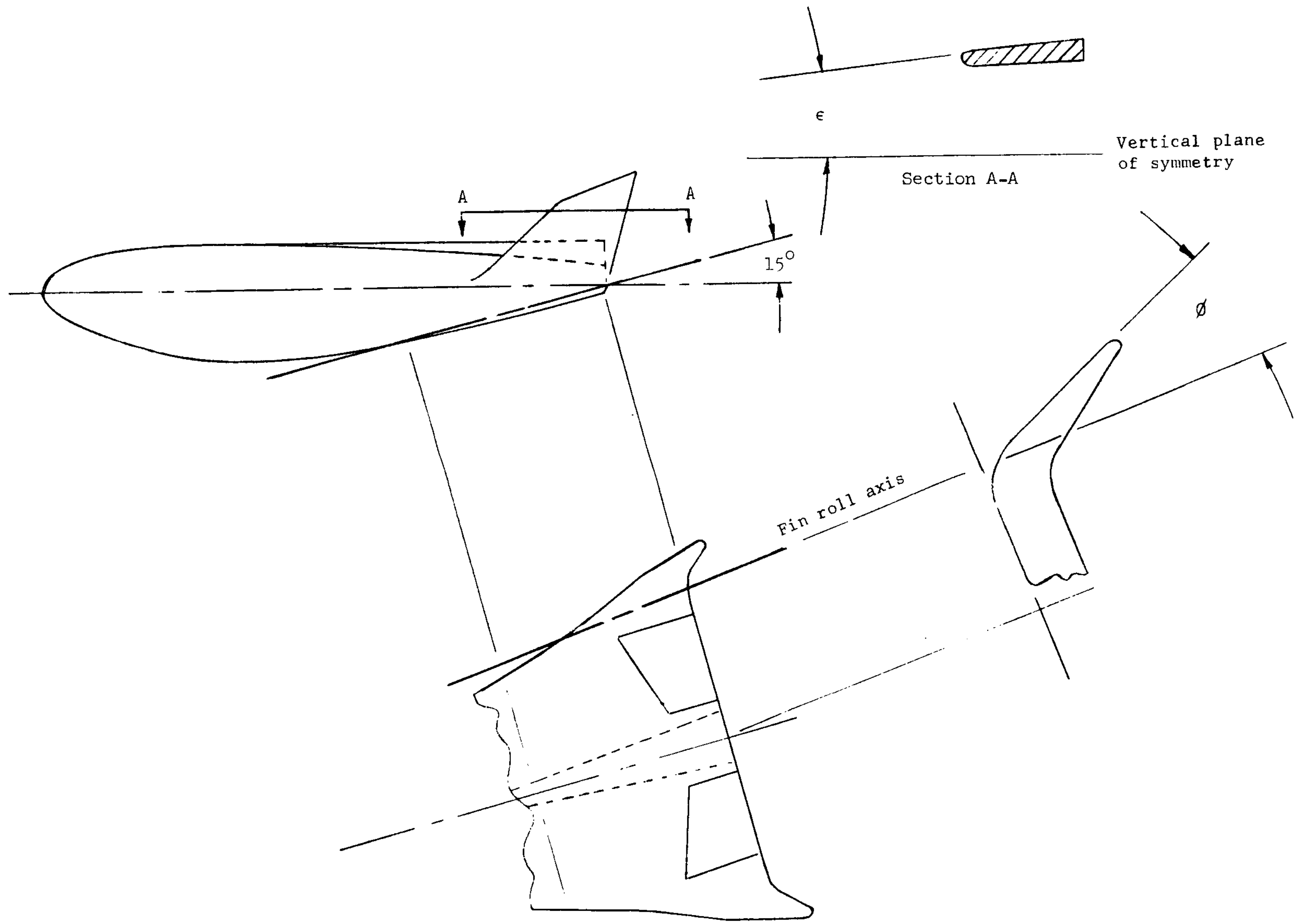
(a) Basic body with center-line fin E_2 and tip fins I_3.

Figure 1.- Drawing of HL-10 model. l = 40.64 cm (16.00 in.)



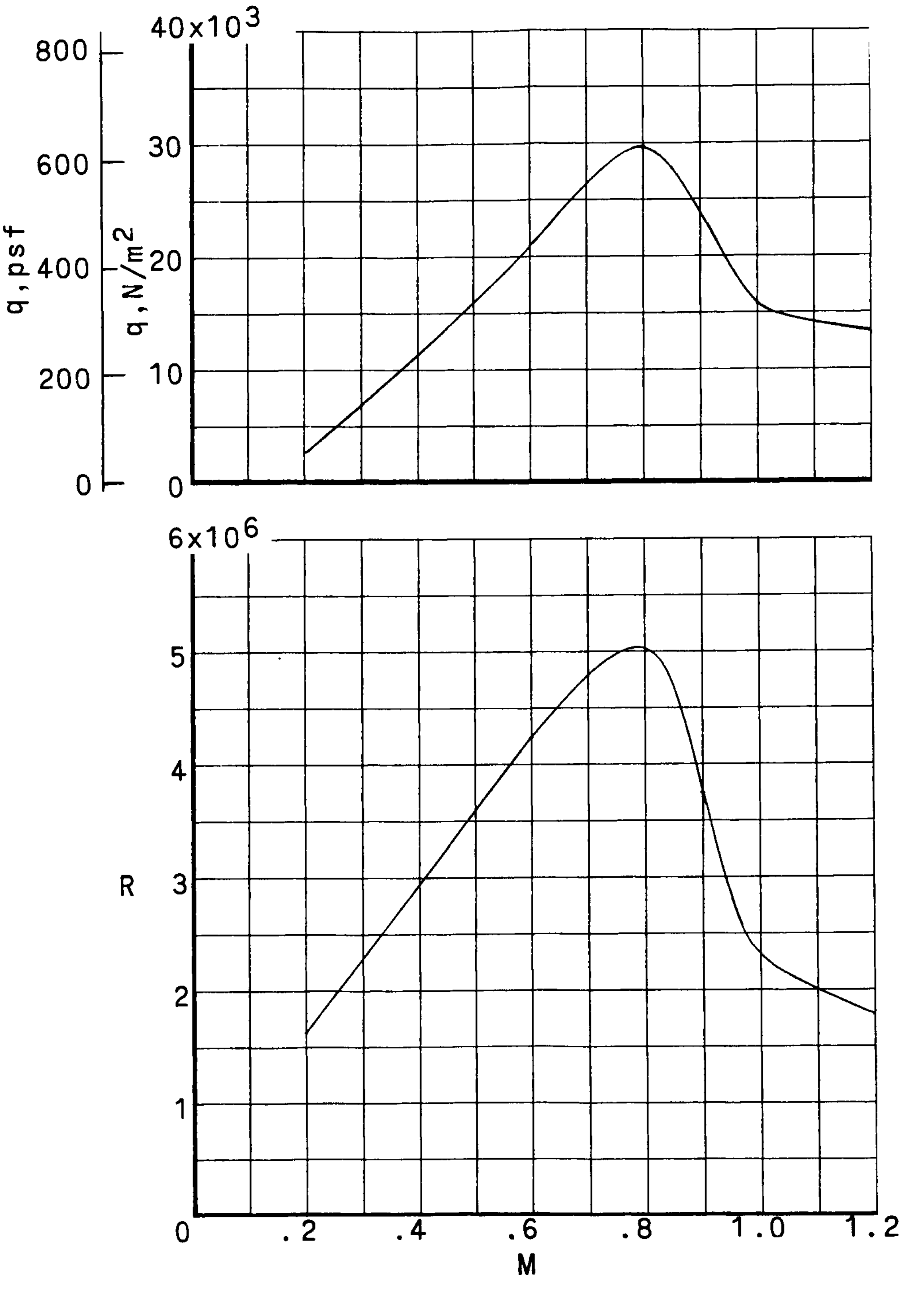
(b) Transonic configuration (basic body with center-line fin E_2, tip fins I_4, and transonic flaps).

Figure 1.- Continued.



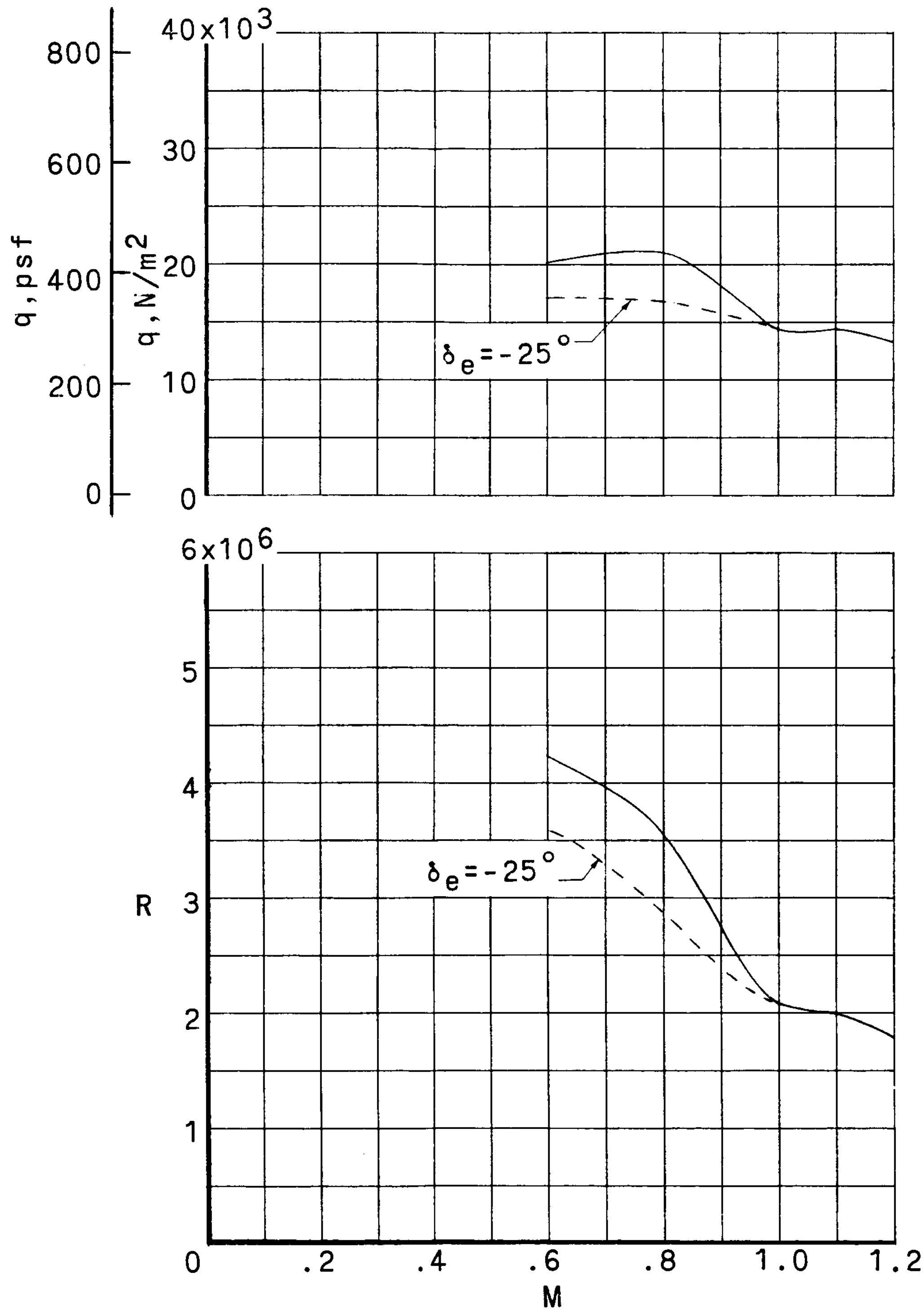
(c) Tip-fin orientation.

Figure 1.- Concluded.



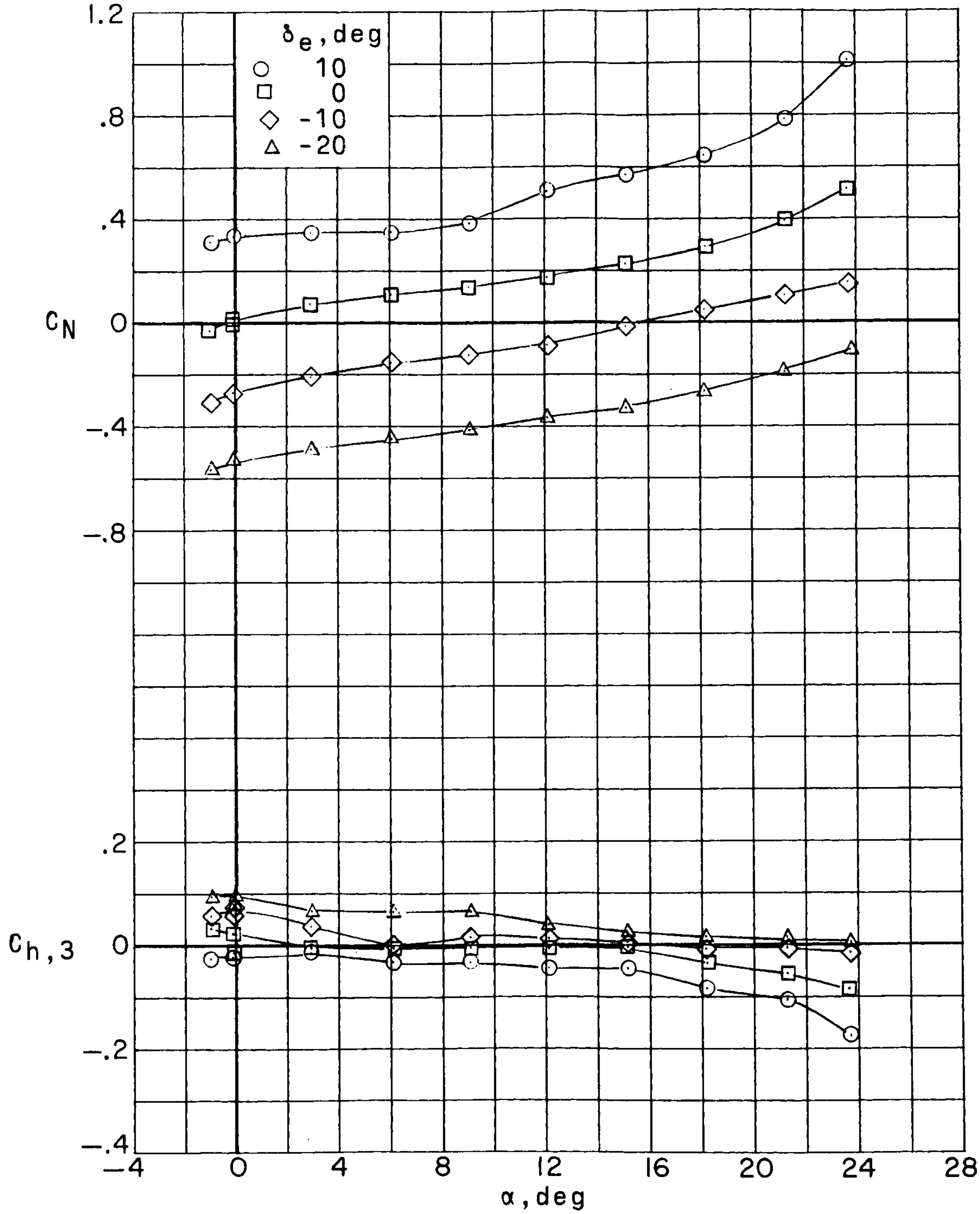
(a) Basic body with center-line fin E_2 and tip fins I_3.

Figure 2.- Variation with Mach number of test Reynolds number based on reference body length, l = 40.64 cm (16.00 in.), and of test dynamic pressure.



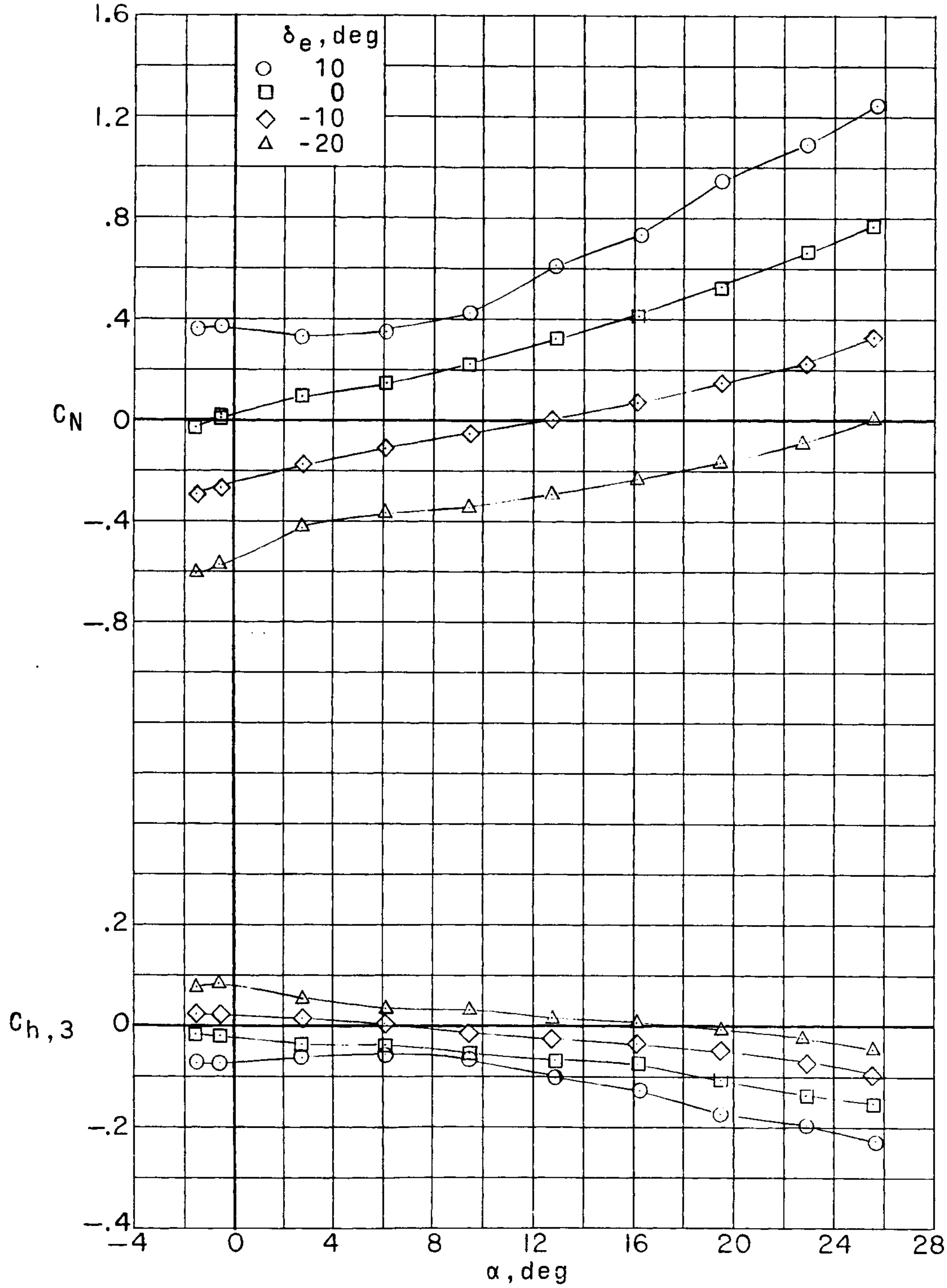
(b) Transonic configuration (basic body with center-line fin E_2, tip fins I_4, and transonic flaps).

Figure 2.- Concluded.



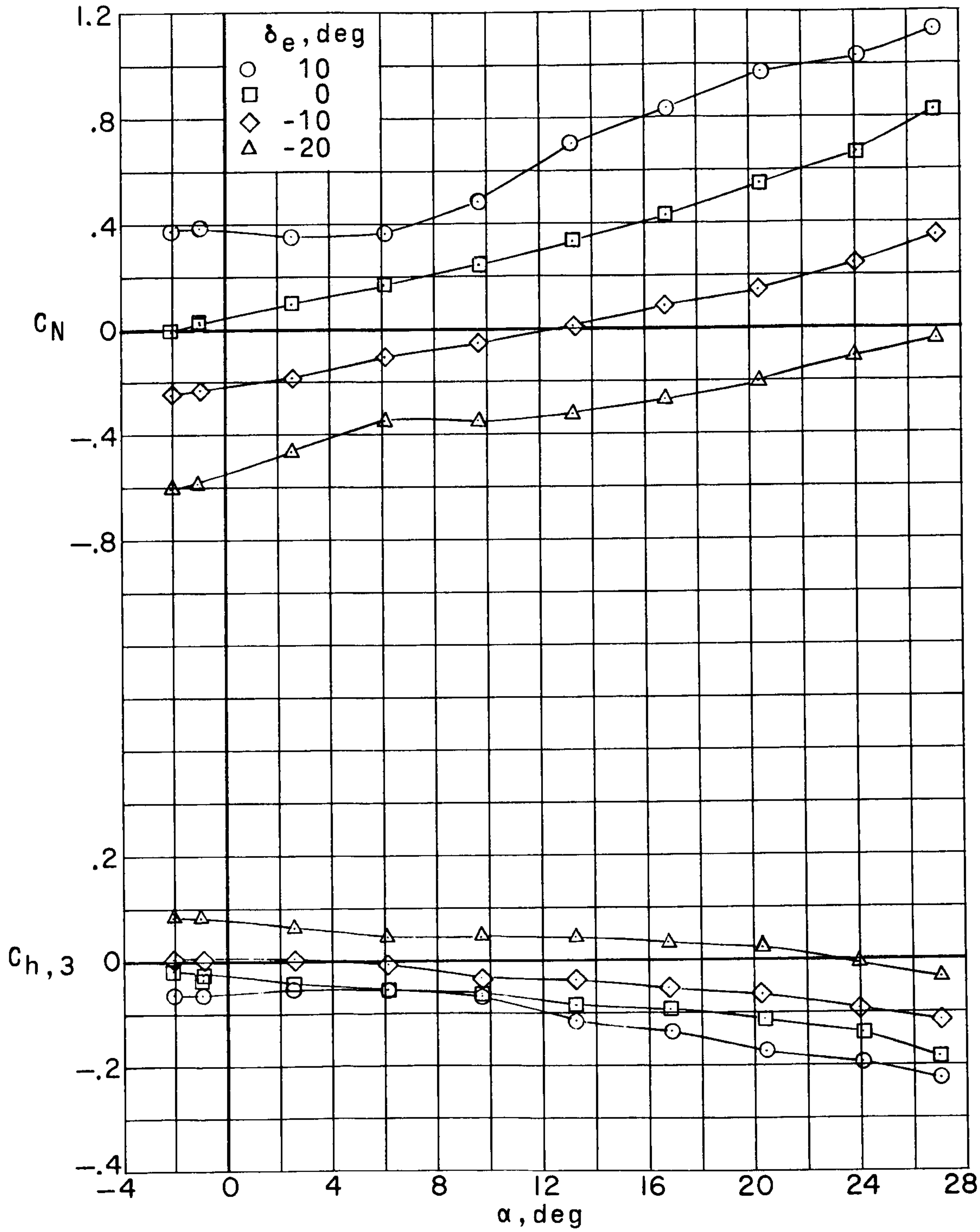
(a) M = 0.20.

Figure 3.- Variation of elevon hinge-moment coefficient and elevon normal-force coefficient with angle of attack. Basic body with center-line fin E_2 and tip fins I_3.



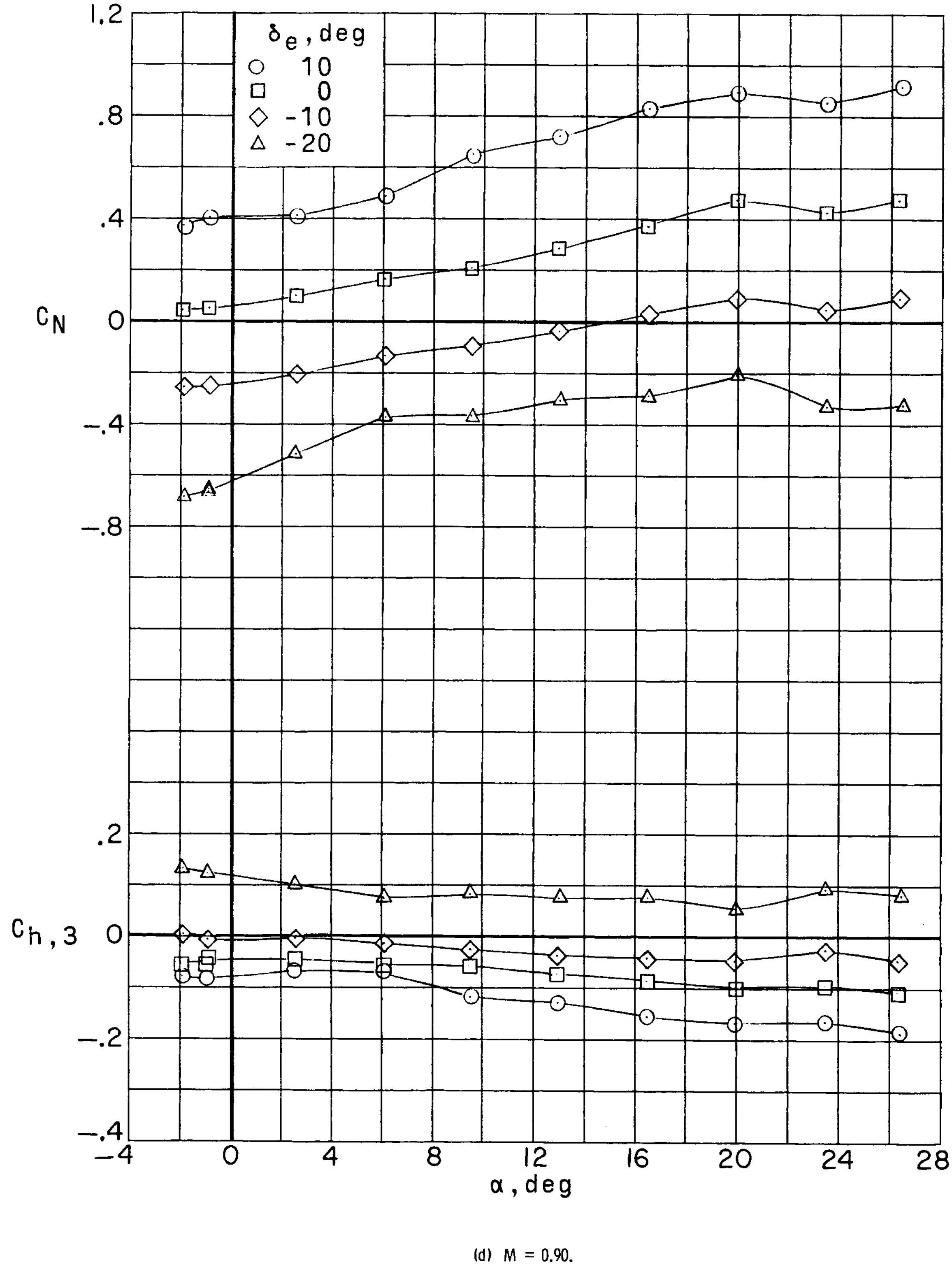
(b) M = 0.60.

Figure 3.- Continued.



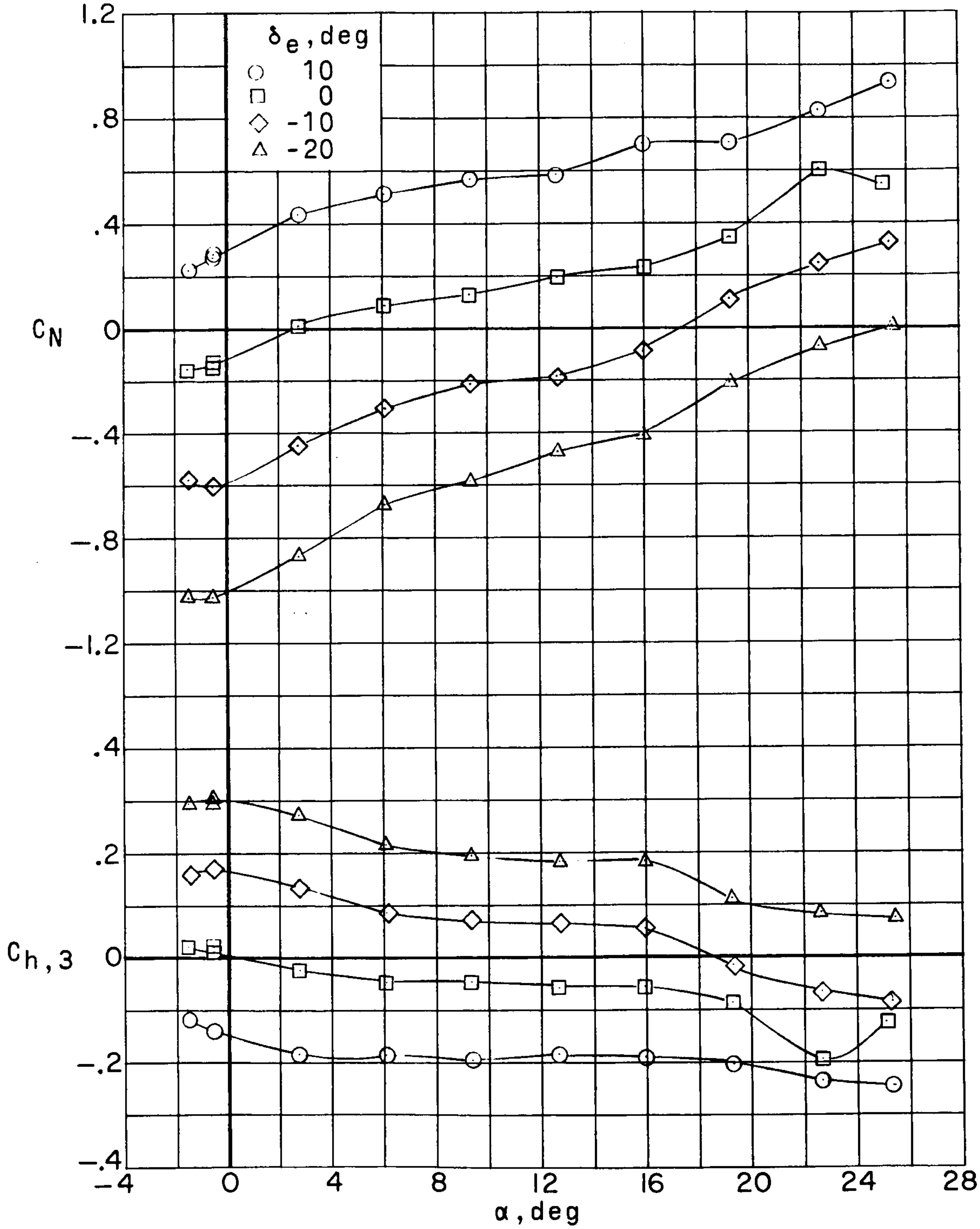
(c) M = 0.80.

Figure 3.- Continued.



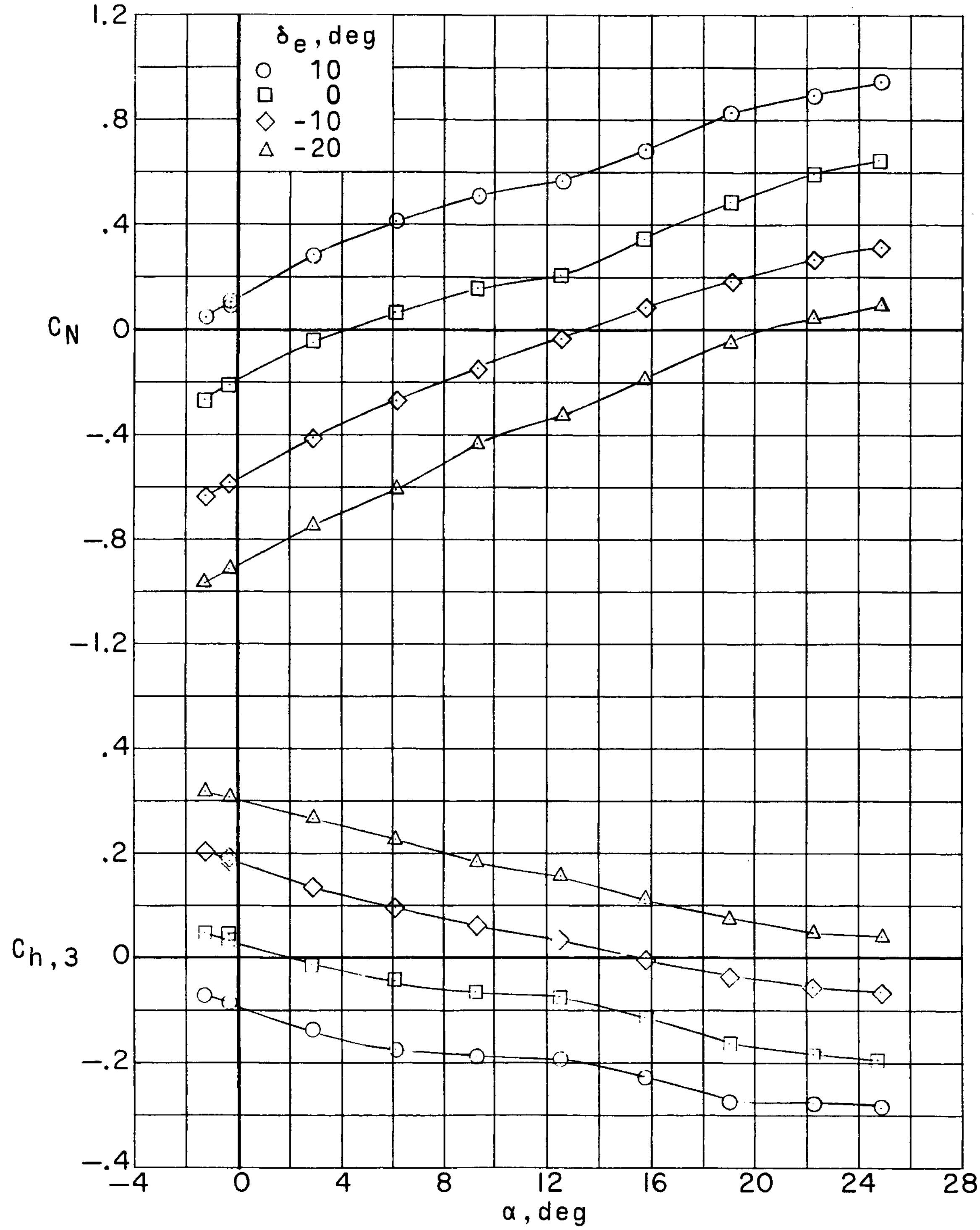
(d) M = 0.90.

Figure 3.- Continued.



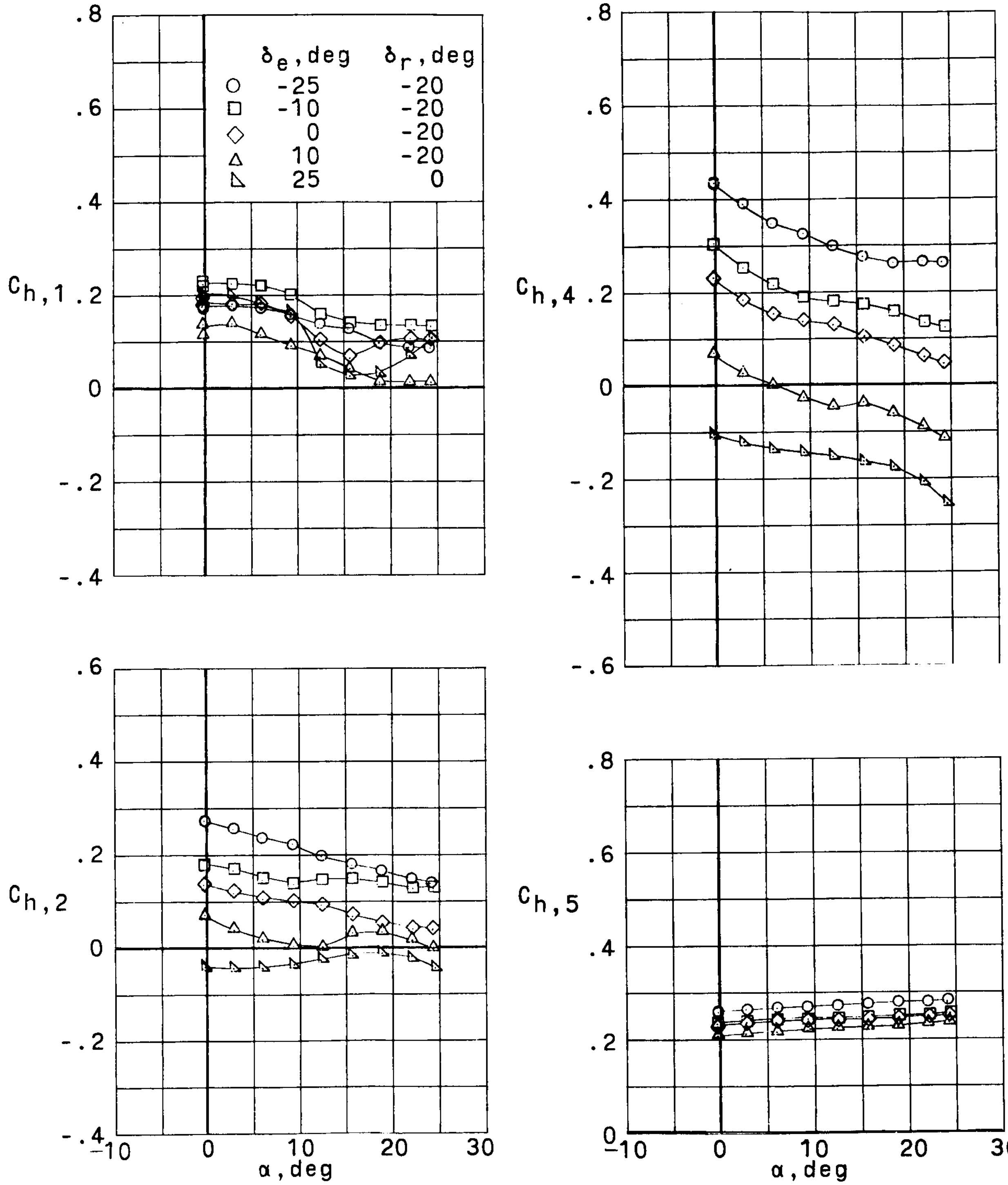
(e) M = 1.00.

Figure 3.- Continued.



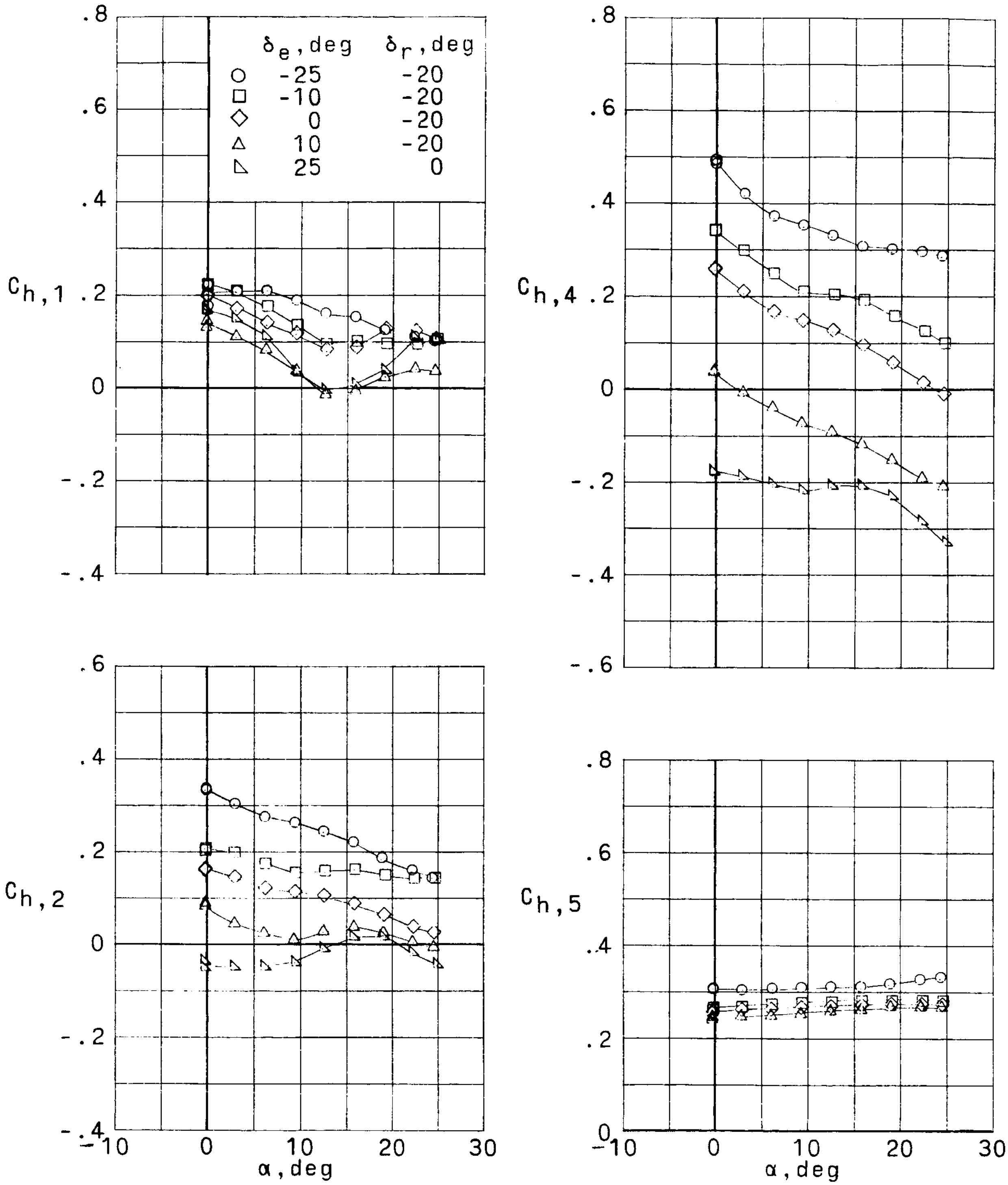
(f) M = 1.20.

Figure 3.- Concluded.



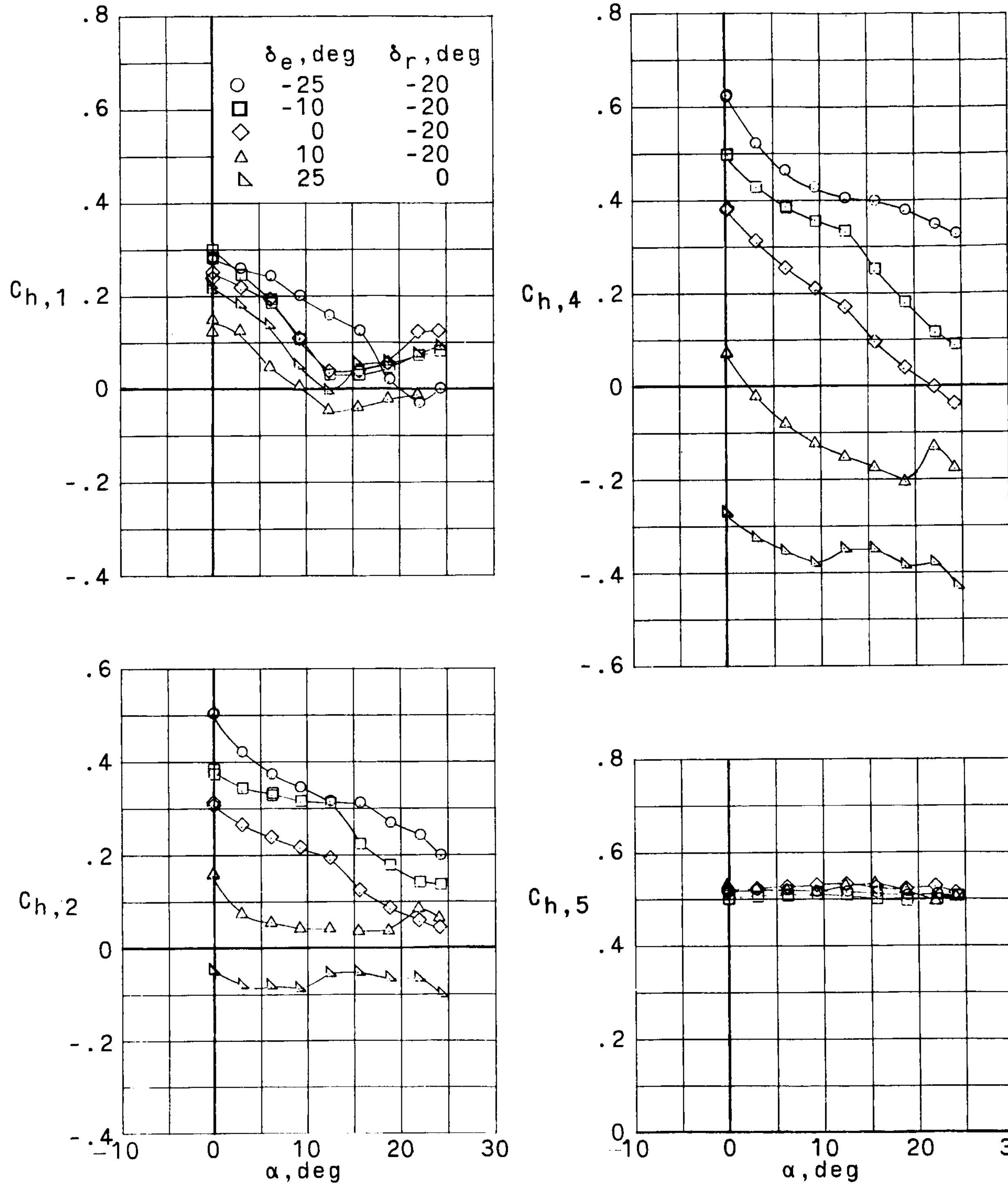
(a) M = 0.60.

Figure 4.- Variation of control-surface hinge-moment coefficient with angle of attack. Transonic configuration (basic body with center-line fin E_2, tip fins I_4, and transonic flaps).



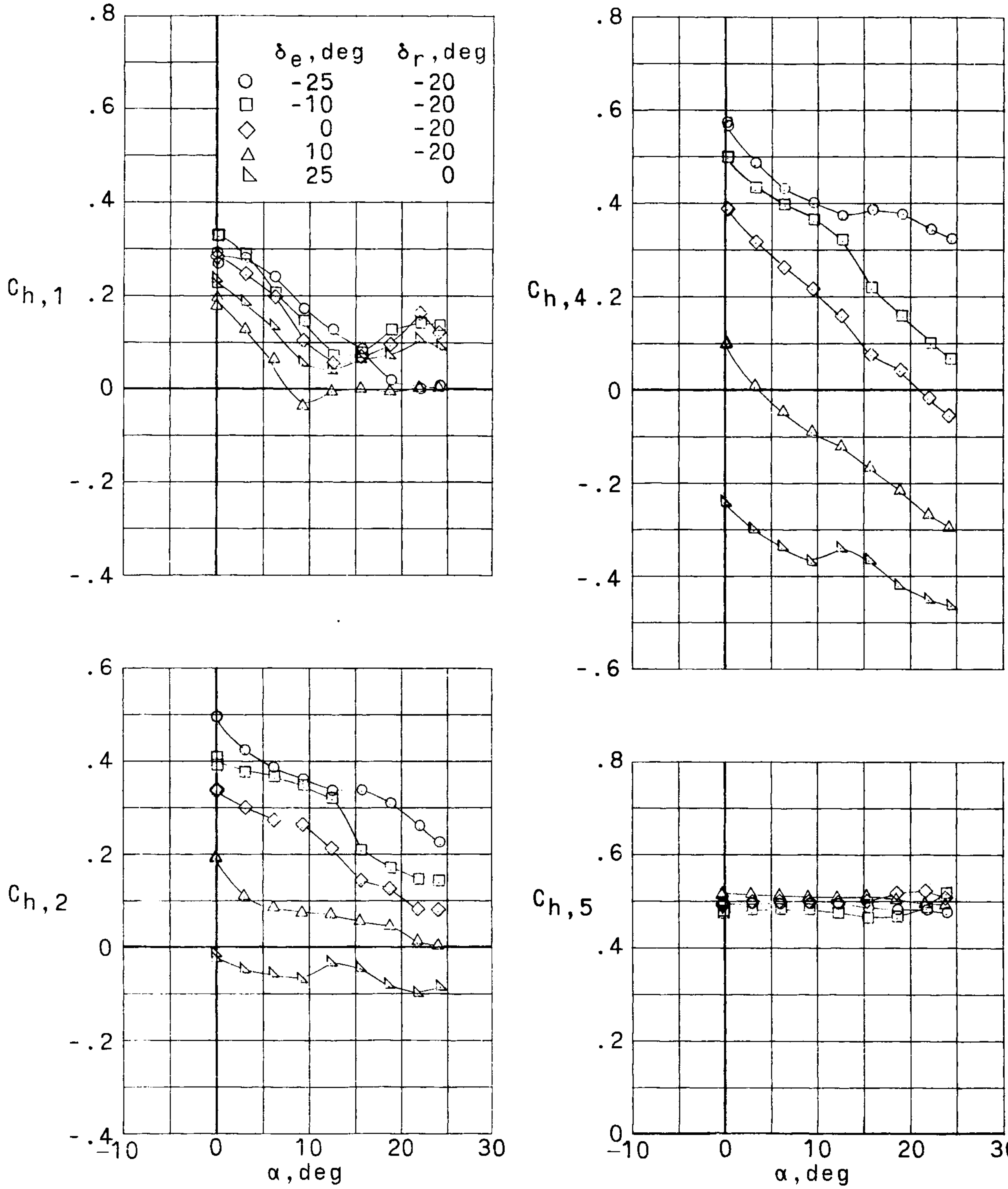
(b) M = 0.80.

Figure 4.- Continued.



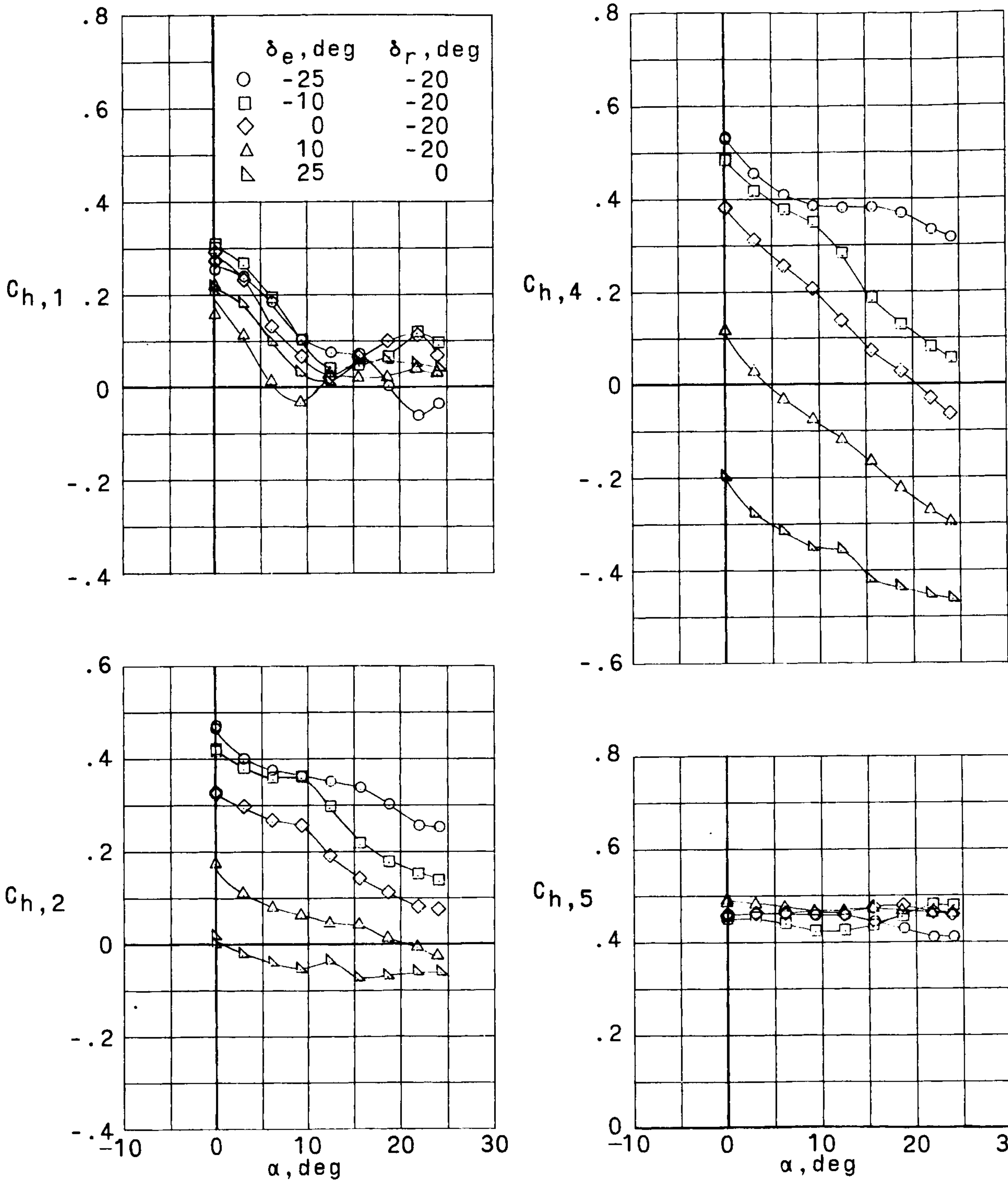
(c) M = 1.00.

Figure 4.- Continued.



(d) M = 1.10.

Figure 4.- Continued.



(e) M = 1.20.

Figure 4.- Concluded.

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